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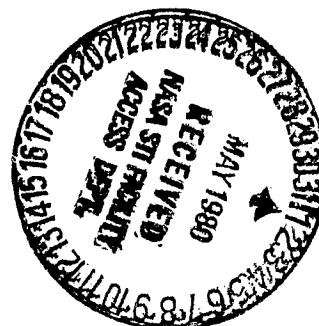
THE SOPHIA-ANTIPOLIS CONFERENCE, FEBRUARY 1980:  
GENERAL PRESENTATION AND BASIC DOCUMENTS

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## General Presentation Memorandum

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### 1. Context

The necessity of managing the national territory and its natural resources in a rational manner appears as a more and more pressing need and is one of the top objectives of the 7th French Plan for Economic and Social Development.

The increasing pressure of these preoccupations with management tends to emphasize the practicality of permanently improving methods for the systematic and periodic collection of data which would permit:

- the establishment and regular updating of inventories of limited resources: air and water, fauna and flora, soil and subsoil;
- surveillance of the various environments and their processes of change whether natural, modified or induced by human activities, for the following purposes:
  - forecasting, detecting and evaluating certain natural or artificial changes considered "dangerous" (erosion of soil, floods, drought, various forms of pollution, clearing of land, etc.);
  - aid for certain economic activities (development and management of certain regions, study of major infrastructures, agricultural and forest operations, mineral and oil prospecting, shipping, fishing, etc.).

Various "traditional" methods are in use at present to obtain this type of information, which is available in the following forms:

- "general" maps (topographical, geological, pedological or relating to vegetation) drawn up from soil surveys and aerial photographs;
- data acquired through studies and censuses carried out periodically by various organizations and administrations (population, housing, agriculture, etc.);
- administrative and statistical files (land register, industrial and commercial establishments, etc.);
- results of measurements undertaken by the systems for evaluating pollution of water, air, soil, etc.;

Even the best of these methods has a number of imperfections; most notably, their slowness, and the operating and updating costs constitute an obstacle: /2

- to obtaining exhaustive, uniform results for censuses and inventories;

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\* Numbers in the margin indicate pagination in the foreign text.

- to quickly drawing up an exact image of a given situation, at a given moment, over a large part of a whole territory;
- to following evolving phenomena.

In contrast to these traditional ground-based methods, remote sensing (remote collection of images of the ground in various colors/wavelength bands) offers a number of particularly interesting characteristics:

- the uniform nature of observations over large areas (one satellite image covers several thousand km<sup>2</sup>);
- repetitiveness, that is, the possibility of obtaining, periodically, at short intervals (of a few days), the same type of data on a given zone, to follow its evolution;
- the "richness" of the data collected and their synthetic character;
- the possibility of speedy processing offered by electronic data processing.

On the other hand, remote sensing obviously presents difficulties of its own. The chief of these results from the fact that the data which are collected are not directly what is sought, and that in order to obtain the latter, it is necessary to process and correctly interpret the physical measurements; this requires:

- the development of appropriate methodologies;
- the establishment of corresponding systems of processing.

Remote sensing does not claim to provide, on its own, a solution to all the current problems of information gathering; it generally intervenes as a complementary method to the traditional systems, by making it possible to facilitate and/or improve the gathering of useful information (greater precision, and/or shorter time span, and/or lower costs).

Essentially, therefore, remote sensing is a means of facilitating decision-making.

## 2. The Available Means - The Basic Principles

The potential of this new technology has seduced a large audience of technicians ever since the first images gathered by the American LANDSAT-1 satellite, launched in July 1972; the continuity of service has been assured since that date by the LANDSAT-2 and -3 satellites, launched, respectively, in January 1975 and March 1978.

The interest of these methodologies should be reinforced, especially /3 for France and Europe whose land areas are small, by the launching during the first part of 1984 of the SPOT satellite, whose construction was decided upon by the French government in September 1977.

While LANDSAT, in fact, does not make it possible to work on a useful scale greater than 1/250,000 (the width on the ground of the point observed is 80 m), SPOT will make it possible to attain useful scales of 1/50,000 and, in some cases, of 1/25,000 (the width on the ground of the point observed is 20 m or 10 m, depending on the mode of operation of the observation instruments aboard the satellite).

The operation of the observation instruments of LANDSAT and SPOT is based on the same physical principles as the functioning of the human eye (observations of different colors in the "VISIBLE" part of the electromagnetic spectrum; however, in addition, one color is observed within the "VERY NEAR INFRARED" portion); essentially, these instruments therefore make it possible to recognize "objects" which are identifiable by means of the human eye, the main difficulties being related to the facts that:

- man is used to recognizing objects "from underneath" and not "from above";
- the levels of detail of the images seen (width of the basic observed point) are not of the same order of magnitude.

Other satellites house instruments which carry out observations in the "INVISIBLE" parts of the electromagnetic spectrum; they are sensitive to physical measurements which are not identifiable by the human eye (and therefore not by LANDSAT or SPOT):

- temperature of the soil and atmosphere (observations within the INTERMEDIATE INFRARED and THERMAL INFRARED);
- electrical properties of the soil (VERY HIGH FREQUENCY and RADAR observations).

Similar instruments of observation may be placed aboard aerial transportation means (aircraft, helicopters) which, in contrast to satellites, present:

- some disadvantages: observed zone is smaller, images much more distorted, higher costs;
- one major advantage, for various applications: their availability can be very high (takeoff a short time after the alert is given) while the passage of a satellite over a given zone may require a wait of several days.

Whatever the instruments used, the preceding considerations show that the images collected are almost never usable in their original state by the final users; they must be the subject of a preliminary interpretation whose aim is to produce "useful" information, corresponding at every point in the image, to the physical signals detected. This interpretation is based on two characteristics of the objects observed: /4

- their structure;
- their "spectral signature" (that is, their "color" in the observed portion, whether "visible" or "invisible," of the electromagnetic

spectrum).

The art of remote sensing thus consists in:

- determining a spectral signature (a "color") that characterizes them in a specific way in relation to their environment;

- listing their basic structural peculiarities;

- when a system of observation specific to this application is under consideration, to select instruments making it possible to detect easily:

- the useful spectral signatures (observation of appropriate colors of the electromagnetic spectrum);

- the characteristic structures (dimensions of the basic point of analysis compatible with the size of the structures to be observed);

- for carrying out this application using existing observation systems:

- pinpointing on the images, either in isolation or superimposed (different colors, different dates), any zones which are uniform with respect to the signal observed;

- either visually (through photo-interpretation)

- or through data processing;

- if required, superimposing grids and/or geographical and administrative boundaries on the processed images.

- attributing a concrete significance to the zones thus identified:

- either in an automatic and theoretical manner by reference to a catalog of spectral signatures, or according to the pronouncements of experts (with photo-interpretation as a special case);

- or by checking on the ground (by surveys in each zone);

- or by a combination of the two preceding methods:

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- ground surveys are carried out in certain zones;

- the same significance is attributed to the entire group of zones presenting the same spectral signature.

The existing observation systems, taken in isolation, are, in theory, perfected for a single application; in order to satisfy most needs, it is therefore necessary to obtain data supplied by several systems.

In this case, it may, for example, be necessary to use spatial or

aerial methods in combination with ground surveys; aerospace observations thus serve to "rough out" the problem and to direct the use of ground systems.

In all cases, the association of the final users with this interpretation process is desirable; in fact, even if it does not always seem necessary from a purely "technical" point of view (and it often is), it is necessary anyway so that the users can take this new source of information into account in their decisions and work methods.

### 3. How to Go from the R and D (Research and Development) Stage to Applications?

The process of development and then of application of the methodologies of remote sensing comprises the following principal phases:

- research of potential applications for data which may be obtained after processing of data collected by the available or proposed means; this phase comprises an appreciable volume of basic research (physical significance of the signal, etc.) and applied research (on methodology);

- for applications which are thought to be feasible, drawing up of a "checking and transfer" program whose object is to achieve a validation of the concept of the applications, studied in a "user" environment; the plans developed in this context can comprise a few limited R and D efforts, as well as an appreciable volume of methodological development.

- setting up of a programme for communicating demonstrated applications, based on several types and means of action:

- information and training for final users;
- carrying out projects in cooperation with the users;
- technical assistance to users after they have acquired a degree of autonomy.

A process like this one is in fact iterative; putting a new tool into service creates part of its applications (emergence of underlying needs which are difficult to list a priori), simply because the users have access to material which makes it possible for them to evaluate the contribution of this tool to concrete examples.

### 4. Status of the Situation in France

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The SOPHIA-ANTIPOLIS seminar is devoted to the four following major areas of application:

- agriculture,
- forests,
- water resources,
- space management.



In these four areas, the present situation in France is characterized in the following way:

- operational government departments and various organizations have been using aerial photography for many years in the course of their normal activities;

- many experiments in remote sensing have been undertaken, the first on the initiative of the National Center for Space Research, with various instruments of observation but basically, since the launching of LANDSAT-1, in 1972, by about forty French laboratories and organizations either at the level of research upstream from applications, or for more concrete ends; files systematically analyzing the most significant of these are collected in the support document, "Analysis of experiments in remote sensing";

- OPIT has begun a "checking and transfer" program (the OPIT evaluation program); this program is described in Appendix 2;

- the information needs more urgently felt, at present, by the French administration at all levels, were surveyed by OPIT and the National Center for Space Research; this survey led to the publication of four volumes, each relating to one of the major areas; these volumes are summarized in the support document "Expressed needs - synoptic tables;"

Historically, experiments were undertaken without any very strict guidelines, in order to explore all the avenues which seemed to offer themselves; in particular, the users of the final data were certainly not closely enough associated with the decision-making process and the orientation of research. This approach led to a situation in which:

- remote sensing technicians believe they have perfected usable products but do not know how and to whom to offer them;

- the final users have not been sufficiently informed of the nature and potential of the methodology;

- on the rare occasions when these two groups have worked together, it has been on a small scale, at the local level while it seems that remote sensing could be a unique tool for synthesis at the regional or national level, or even the European level;

- the absence of a comparative statement of the technical results attained and the stated need for information led to the orientation of programs being decided without defined economic priorities, which probably results in an excessive weight being accorded to certain themes, and to insufficient attention, or none, being paid to others.

This observation has given rise to the SOPHIA-ANTIPOLIS seminar.

## 5. Objectives and Organization of the Sophia-Antipolis Seminar

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The basic objective of the seminar is to set up a dialogue between technicians and final users, in order to establish priorities as well

as bases for joint action. For this purpose, we have brought together:

- French users whose centers of interest are on a national level in some cases, and a regional or departmental level in others;
- French remote sensing technicians whose areas of expertise cover the four areas of application concerned;
- foreign users presently taking part in operations evaluating the contribution of remote sensing in their respective fields; these users belong to:
  - the U.S. Department of Agriculture (USDA);
  - the U.S. Army Corps of Engineers (equivalent to the French "Directions de l'Equipement");
  - the Quebec Ministry of Lands and Forests.

The seminar proceeded with a work sequence of:

- workshops (discussions between users and technicians on concrete cases in each of their respective fields of application);
- operational groups (users in one group, technicians in another);
- full sessions.

The purpose of this work method was to permit the two communities (users and technicians) to establish a dialogue while leaving them the possibility of reflecting separately in order to draw up proposals stating their respective points of view.

Apart from the preparatory documents already mentioned earlier, the participants could also find food for reflection in the following memoranda:

- technical synthesis memorandum;
- "Bibliographical approach to operational applications of remote sensing," briefly presenting the principal characteristics of the most significant experiments with regard to the various requirements surveyed;
- probatory system for the observation of the Earth (SPOT);
- EARTHNET informational memorandum (products distributed by the GTDA).

## 6. Questions to Which the Seminar Should Find Answers

By the end of the seminar, it is desirable that some elements of answers should be provided to the following questions:

A. From the point of view of the experiments and information presented, what are the needs likely to be more or less satisfied with the help of remote sensing (existing or proposed means)?

B. How can we evaluate the results and contribution of remote sensing?

C. Given both their relative economic importance, on the one hand, and the characteristics and performances of the traditional corresponding means of information gathering, on the other, what hierarchy of priorities should be established for assessing needs which are likely to benefit from remote sensing?

D. Of the various top-priority needs, which are the final users who could serve as subjects for setting up demonstration programs? What could be the modalities for carrying out projects with these subjects?

E. What methodological studies should be most urgently undertaken for the operational use of existing data?

F. Should we develop or request certain basic research programs?

G. Is the development of certain observation instruments desirable in order to satisfy high priority needs?

H. To facilitate the preoperational evaluation and experimentation phase of remote sensing, is it desirable to establish in France an ad hoc program and organization? (Participants can base their reflections on Appendix 1.)

I. In what context should repetitive operational projects be carried out (central or decentralized, specialized or general, public or private sectors)?

#### NASA's "Technology Transfer" Program

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##### 1. Context

After an initial phase of exploration of the potential application of the information which can be obtained by processing data gathered by LANDSAT, NASA designed a transfer program for this new technology which comprises two phases:

- demonstration of the value of the information supplied;
- dissemination of information on the applications demonstrated, to the entire group of users concerned.

The demonstration of the value of information supplied is based on the ASVT (Applications System Verification and Transfer) which was launched in 1975, and whose objective is to furnish a "concept validation" of the applications studied, in a "user" environment.

The dissemination of information on the demonstrated applications is based on several types and means of action:

# WORK PROGRAM

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NORMAL TIMETABLE: 8:30 a.m. to 1:00 p.m.  
and 2:30 p.m. to 6:00 p.m.

	FULL SESSION	OPERATIONAL GROUPS	WORKSHOPS
<p>MONDAY 2:30 p.m.</p> <p>3:15 p.m.</p> <p>4:30 p.m.</p>	<p>Opening of seminar. Final information on program and organization.</p> <p>Presentation of conclusions of the operational groups. General discussion and adoption of a common theme for the seminar.</p>	<p>Discussion and final editing of "position papers." What each group at the conference expects from the other. Discussion of the concept "operational."</p>	
<p>TUESDAY 8:30 a.m. - 1:00 p.m.</p> <p>and</p> <p>2:30 to 6:30 p.m.</p>			<p>Examination and discussion of concrete cases. Drawing up of answers to point A.</p>
<p>WEDNESDAY</p> <p>8:30 a.m.</p> <p>10:45 a.m.</p>	<p>Presentation of workshop conclusions</p> <p>Discussion of point B and conclusions</p>		

	FULL SESSION	OPERATIONAL GROUPS	WORKSHOPS
2:30 p.m.		Discussion of points: C-D, users E-F-G, technicians	
THURSDAY			
8:30 a.m.	Presentation of conclusions of operating groups. Discussion and synthesis.		
2:30 p.m.		Examination of points H and I and conclusions of users and technicians.	
4:30 p.m.	Discussion of conclusions of operating groups on points H and I.		
FRIDAY 8:30 a.m. - 11:00 a.m.	Presentation of general syntheses. Discussion and adoption of conclusions of the seminar. Closing.		

Workshops: Agriculture, Forests, Management-Environment-City Planning/  
Water.

Operating Groups: Users, Technicians.

- three regional centers having the skills and means to ensure:
  - information and training for users;
  - carrying out of projects in cooperation with users;
  - technical assistance for users after they have acquired a degree of autonomy.
- working relations have been established with local decision-making bodies (National Conference of State Legislatures, National Governor's Association, State interagency commissions, etc.); the aim of this type of action is:
  - better identification of local needs;
  - increased awareness on the part of these bodies of the methods and applications of remote sensing by:
    - organization of information sessions and regional workshops;
    - distribution of "user guides" to local government, industry and universities;
  - winning the participation of these legislators in defining and planning of future NASA programs.
- NASA encourages the formation of an association of remote sensing industries; the objective is to permit the companies and private organizations who supply services, products and equipment for remote sensing to play an increasing part in satisfying user needs;
- the "University Applications Program" of NASA is a major tool for setting up independent research, training and consultation centers, distributed throughout the user community; in particular, the aim of this program is to place a consultant function at the disposal of the various American states in their own universities; /11
- various major analysis programs have been documented and are available to the public through the intermediary of an information center located at the University of Georgia (COSMIC);
- software for analysis has been introduced, on a time sharing basis, in a data processing network on the federal scale (COMNET); access to this system, easy and inexpensive, is offered to users for the duration of exploratory and application implementation phases only.

## 2. The ASVT Program (Applications System Verification and Transfer)

As stated previously, the aim of this program is to provide "concept validation" for the applications studied, in a user environment.

The products of an ASVT take the form of validated methods and techniques for using satellite data, to solve operational problems.

To ensure the validity of the evaluation of the application studied, ASVT projects are selected on the basis of the following criteria:

- real "user" needs are explicitly stated;
- potential large scale market development; favorable return on investment;
- probable feasibility;
- no demonstration carried out previously;
- related to currently unsolved national problems and to NASA's priorities;
- significant user participation;
- operational use planned by the user;
- one of the organizations participating in the project may act as leader of the users;
- industry or university participation (if necessary);
- NASA participation for a limited period of time.

In general, the preceding criteria have proved good indicators of the degree of success of NASA technology transfer projects; 19 different ASTV projects have been undertaken up to the present.

ASTV projects can include some R and D initiatives, as well as an appreciable volume of methodological developments.

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### 3. Regional Technology Transfer Centers (Regional Remote Sensing Application Centers)

These centers, three in number, serve as principal points of contact between NASA and the different American states located in their respective zones of activity.

The necessity for these centers became apparent following the disappointment felt by the American states as a result of the first contracts which they awarded to the industry; since they did not have a sufficient grasp of the potential offered by remote sensing, they had provided specifications which were too vague, and obtained inconclusive results.

The mission of these centers is to transfer systematically, first of all to the governments of the various states and to local communities, the capacity for using LANDSAT data efficiently in decision making relating to resource management and planning.

The aim is to make these governments and communities independent users (not merely assisted users) receiving technical support

from one or more resource groups:

- internal structures who have acquired the necessary skills;
- local universities;
- private industry.

This transfer is carried out by dissemination of low risk applications which have previously been developed, demonstrated and validated (ASTV program).

This type of intervention does not, in theory, comprise R and D initiatives or methodological development.

In the longer term, after the users have acquired autonomy these three centers can ensure permanent assistance in transferring new technologies, excluding all routine operational activity.

In the latter perspective, one of the roles of the centers will be, if not to maintain a library of all operationally validated methods, at least to put users with problems in contact with others who have found a solution to a comparable difficulty.

### 3.2 Modes of Intervention of the Centers

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Projects undertaken jointly with final users are the key to the centers' mode of intervention. So that these projects can give rise to an effective process with a future, the centers intervene only when four preconditions occur together:

- the project is implemented following a political decision by the state, whether implicit or explicit, to use this type of data;

- there exists, or can be established, a group coordinating the various state administrative bodies likely to benefit from the projects's contribution;

- a dynamic individual leader, highly motivated toward the use of remote sensing (the success of his work depends on it, for example), can bring the energy necessary for the success of the project and ensure its coordination;

- the necessary data processing resources are available on site.

The centers also organize user symposiums during which:

- users can share their experiences, which represents a critical phase in "lateral" (inter-user) transfer, which should develop as soon as a technology becomes operational;

- possibilities for display and demonstration are offered to service and manufacturing companies to give them the chance to become better acquainted with the users, who are all their actual and



potential customers.

Each of the three centers provides newsletters which help keep users informed of the activities in the various states.

### 3.3 Description of a Typical Intervention

A typical intervention takes the following course:

1. the center involved invites the "state" and shows how LANDSAT data can be used and interpreted (2 to 3 days);
2. "the state" proposes one or several projects;
3. a team from the center evaluates their feasibility with respect to LANDSAT and selects the one, or ones, relating to applications previously demonstrated;
4. "state" staff come to the center to follow a "course" of one or two weeks during which they receive the basic training necessary for the preparation and carrying out of the project (theoretical courses and workshops);
5. carrying out the project; the center does not take part either in the collection of the true ground data, or in evaluating the exactness of the results of processing; it is up to the user alone to carry out such an evaluation, particularly by comparison with information gathered by means of the traditional systems.

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During such an intervention, then, the role of the center is:

- initially, to provide information to the state, by means of conferences and by supplying images of the corresponding region (especially on the interactive system);
- later, to train state teams to interpret images (excluding any training in computer analysis and programming);
- if necessary, to play the role of consultant to the state where, for example, the choice of the computer to be installed is concerned (= choice of supplier).

The center supplies:

- data for the cost of reproduction only;
- support (training phase) and software at no cost.

The State provides:

- its own staff;
- the data processing resources it has at its disposal;
- the ground data.

This type of intervention excludes any direct financing of the State by NASA.

### Memorandum on Evaluation

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The potential user of remote sensing methods is essentially interested in the operational applications of this technique.

The term "operational" deserves some attention. As applied to remote sensing, it concerns the various links in the chain of data processing and utilization; the technical process of obtaining a result, as well as the utility of that result.

OPIT, on the occasion of a study tour in North America, and to give a firmer base to its expert studies, was led to provide itself with a definition of this concept:

We considered as operational any application of remote sensing whose reliability is known and accepted, which is renewable, not necessarily irreplaceable, and free of any aspect of research. In this case it is generally supported financially by the user, to whom one can therefore suppose that it renders a real service. It may be the improvement of a decision-making process, and the support obtained may then sometimes be measured in economic and financial terms to the extent that it concerns a very circumscribed process in the field of the activities of the market economy. It can also take part in a production process (cartography).

By reliability we mean here the exactness of the information supplied by remote sensing in terms of the user's specifications.

This formula is proposed as a starting point for a discussion which it will be necessary to have at the start of our work, from which we expect to provide ourselves with a common vocabulary, essential to avoid a degree of confusion in debate.

To fill what we have always considered as the principal requirement of users with respect to remote sensing, OPIT has defined a systematic program of experimentation and evaluation.

The need for this program of experimentation and evaluation arises from the following experimental observations:

- The same processing of remote sensing data can give very different results (in the sense of the reliability of the response given to an identical question) in zones whose natural characteristics are different.

- Different processing (in the sense that the statistical hypotheses on which it is based are different) applied to the same remote sensing data can give very different results (again in terms of reliability).

For these reasons, it is not possible to generalize, a priori, in a valid manner for the entire territory (an for existing data processing systems as a group), concerning the results obtained by a given processing system in a particular region. For this it is necessary to experiment conclusively in advance, using this or these data processing systems on a statistically significant sample of the geographical variability of the territory in terms of remote sensing. /16

- This variability is due to many causes (geological and pedological substrate, morphology, climate, etc.) which are analyzed bibliographically and drawn from the first French experiments in remote sensing. On the basis of these studies, OPIT divided the national territory into 19 physical units within each of which the stability of results given by remote sensing should be observed. On page 18 will be found the map of these zones and, on page 19, their significance.

The experimentation and evaluation program consists, first of all, within each of these units, in selecting a sufficient number of test zones for each of the users' needs, then of activating in each of these zones the various processing systems able to give a response to the questions (needs) posed.

As for the evaluation, it comprises two phases: one purely objective, intended to measure the reliability of the different methods in their response to the present questions (a priori specifications, independent of remote sensing); the other to explore, in the results furnished by remote sensing, the original content (not conforming to the a priori specification) which may be usable in carrying out the users' missions. These two phases are complementary and constitute the preliminaries for what may be considered as the mutual adaptation of the remote sensing tool and its efficient use.

Objective measurement of reliability will be possible through the systematic comparison of each result obtained through processing with real conditions observed on the ground, in conformity with the user's specifications ("true ground conditions"). This comparison is possible through the existence of a data processing program designed and carried out by OPIT, which compares, zone by zone, the true ground conditions and the results obtained by data processing.

The outcome of the OPIT experimentation and evaluation program will thus take the concrete form of immediate availability of information of the following type:

in what physical unit, known by its boundaries, which processing system, used by which organization, gives the answer to a given question or meets a given set of specifications, with what degree of reliability (percentage of correct responses classified);

or

to resolve a given question, posed at a given place in

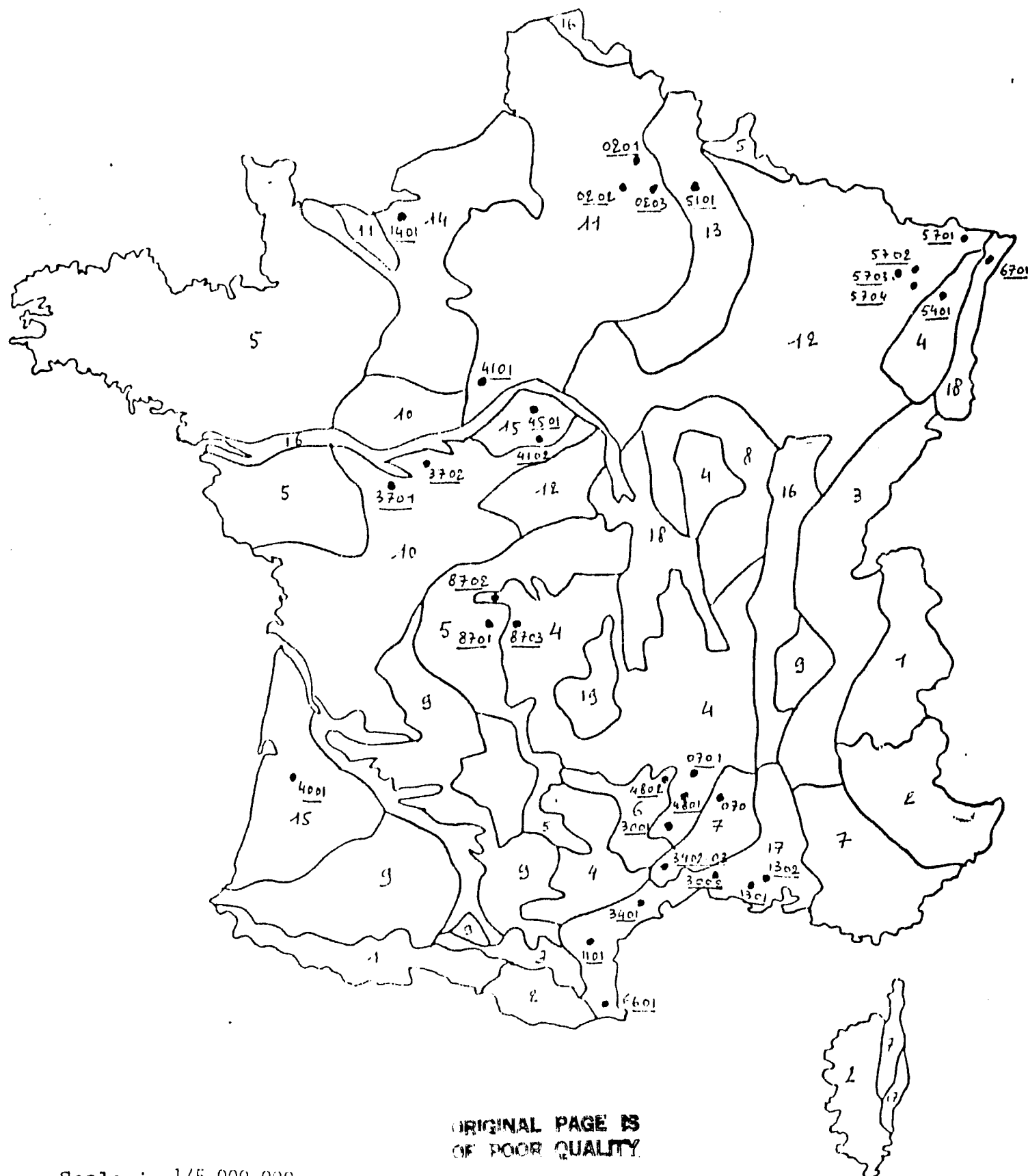
a given physical unit, it is advisable to use:  
a given processing system (to be found at a  
given organization, with given conditions of  
costs and delays) and you will obtain a given  
level of reliability.

In this phase of objective evaluation, as in that of exploratory investigation of the unexpected services that this technique can provide in decision-making processes, the participation of users is essential. /17

They are the ones who, at the beginning of the experimental stage, are called on to define the tasks with which remote sensing will be confronted, as it is obviously necessary to establish priorities within the great variety of needs felt by the various services involved. In practice these priorities have been debated and finally settled following systematic investigations into the expressed needs, during meetings attended by representatives of the principal services concerned (OPIT/CNES study).

The program is thus oriented around four major themes: forests (identification of wooded areas, clearing, forest fires, determining the types of tree populations, distinguishing the species), agricultural production (identification and continuing study of grain producing areas, inventory and continuing study of types of meadowland); water resources (inventory of free-water-covered surfaces and humid zones, water quality, moisture content of soils); management (soil use, artificially prepared surfaces and natural environments).

It is also essential, at the level of collecting data on true ground conditions, to have, once again, the participation of the users who are in the best position to assign the physical realities of the ground phenomena to the categories within the specifications they use.



Scale : 1/5,000,000

Zone No.	Significance
1	Mountain ranges of the Alpine type: Northern Alps, Pyrenees
2	Mountain ranges of the Alpine type under Mediterranean influence: Southern Alps and Eastern Pyrenees
3	Folded sedimentary system of pre-Alpine type - brown soils, red rendzina, lithosols
4	Moderate mountain ranges of Hercynian type. Acid brown soils, podzols, lithosols
5	Low Hercynian plateaux with prevailing oceanic influence and a tendency to mixed woodland and pastureland, acid brown soil. Leached (brown) soils
6	Karstic plateau of the Causse type. Red rendzinas
7	Compartmentalized sedimentary groups with prevailing maritime influence. Rendzinas, lithosols
8	Peripheral depressions and sinkage basin near or in enclaves of Hercynian mountain range
9	Foothills and calcareous hills, dissected and compartmentalized. Leached soils, brown soils
10	Calcareous or marly plateaux under maritime influence, of the Aquitanian type. Rendzina soils, brown calcareous soils and leached soils
11	Alluvial plains and plateaux (center of sedimentary basin). Brown soils
12	Secondary plateaux without very marked relief and cuesta phenomena (periphery of sedimentary basin). Maritime climate shading to continental. Rendzina soil and eutrophic brown soil
13	Dry chalky plateaux in modified maritime climate. Rendzinas
14	Chalky plateaux covered with alluvial deposits with a tendency to mixed woodland and meadowland. Markedly maritime climate. Leached brown soils, calcareous brown soils
15	Sands of continental spread with forest-based economy. More or less well developed lake or marsh system. Podzols.

(Table continued on following page.)

Table, cont'd.

Zone No.	Significance
16	Valley bottoms. Recent fluvial, alluvial deposits.
17	Fluvial, alluvial deposits and low-lying fluvial plains under prevailing Mediterranean influence
18	Tertiary sinkage plain with semi-continental or continental climate
19	Recent volcanic mountain range with moderate mountains and maritime influence. Leached soils. Brown calcareous soils

Recording of remote sensing data is usually in data files on magnetic tape.

In the case of LANDSAT, for example, there are more than 7 million basic image points (pixels) for each image.

Each image represents an area of about 185 by 185 km on the ground.

For each pixel, 4 radiometric values are recorded in 4 spectral bands (channels):

- channel 4 from 0.5 to 0.6  $\mu\text{m}$
- channel 5 from 0.6 to 0.7  $\mu\text{m}$
- channel 6 from 0.7 to 0.8  $\mu\text{m}$
- channel 7 from 0.8 to 1.1  $\mu\text{m}$

This gives almost 30 million radiometric values per image.

Remote sensing must make it possible to convert this numerical data into an operational image.

#### A. Corrections

##### I. Geometrical Corrections

When the documents required must be able to be superimposed on topographical maps, or when results obtained on different dates are being compared, it is necessary to correct the geometrical distortions in the recordings (due to the acquisition system, to variations in the attitude of the receiver, etc.).

The most frequently practiced corrections use landmarks whose geographical coordinates are known, and calculations based on the law of distortion.

##### II. Radiometric Corrections

The fact that the atmosphere is interposed between the ground and the receiver leads to disturbances in the radiometric measurements.

With the aid of an object whose position on the ground is unvarying (a town for example), it is possible to adjust one image in relation to another, and thus measure the actual evolution of the phenomena.

Radiometric corrections also make it possible to express measurements in the infrared band in absolute temperature and to translate into terms of reflectance data measured in the visible spectrum.

#### B. Optical and Photographic Data Processing

Remote sensing visualization corresponds to the recording of data



on photographic or graphic (printer) support devices.

#### I. Visualization by Channel

It is possible to visualize separately, in black and white, the primary channels, by attributing degrees of grey or graphic symbols to the radiometric values.

#### II. Colored Compositions

This is a synthesis document, integrating the variations observed on the primary channels.

One color is assigned to each channel and the documents thus obtained are superimposed.

The appearance of the documents varies greatly depending on the conventions adopted in assigning the colors (e.g. for LANDSAT, channel 4 is yellow, 5 is red and 7 is blue, giving images which resemble classic infrared color photographs).

#### III. Improvement of Images

It is possible to improve the reading of images by means of data processing (optical but also numeric) which enhances contrast, emphasizes the boundaries of phenomena, and changes the dynamics (spread of values over parts of images, for example).

#### IV. Photographic Interpretation of Remote Sensing Data

All these documents obtained from photographic support devices can be subjected to photographic interpretation just as can classic aerial photographs (establishment of zones, thematic maps, etc.).

The advantage of photographic interpretation is still the integration of these forms by the human mind, an integration which is difficult to perform automatically by computer (a task requiring a long and complex data processing system, which is currently being worked out).

#### C. Numerical Processing

These deal essentially with the radiometric values of the pixels and are intended to group these pixels in order to obtain images conforming to the objects which are to be cartographically treated.

It is necessary to use a "statistical hypothesis" to group these pixels, a criterion of radiometric proximity which can be variable in nature: each criterion will have its own result and must be adapted to the object which is to be picked out and identified.

#### I. Supervised Processing

This method calls for ground data from the start of processing.

It consists of locating, on the ground, zones which are as

representative as possible of the phenomena which are to be observed and which serve to establish a relationship between the radiometric measurements and the contents of the zone.

The ground data collection and the remote sensing recording must be made more or less simultaneously, depending on the phenomenon to be observed (water, for example, requires perfectly synchronized recordings).

The processing consists of extending to the image as a whole the preestablished relationship based on the test zones, by grouping pixels according to the statistical hypothesis.

One hypothesis which is often used is the Gaussian hypothesis of effective measurement (e.g., the amount of energy in wheat crops follows a Gaussian law).

The data processing must incorporate a rejection threshold: if the measurement is "too" different from the average, the pixel is not classified as wheat.

## II. Unsupervised Data Processing

This type of processing does not require ground data a priori. It does not furnish maps (with legend) but images, which are easier to interpret than the original images.

Among the large numbers of measurements, the statistical hypothesis defines "radiometrically close" measurements and groups them in a small number of categories established previously (usually from 5 to 15).

In order to define the "radiometrically close" points, several statistical hypotheses are used (Euclidian distances,  $\chi^2$  and Sebastian, for example).

The results must be interpreted a posteriori using the ground data and reference maps.

## III. The Interactive Methods

These are supervised methods in which the operator can follow on a screen the progress of data processing and judge the pertinence of the intermediate results, so as to "adjust" the process.

## IV. Format of Results

The results can be obtained:

-- on a printer (alphanumeric, electrostatic). Each pixel is represented by a character.

-- on a tracer (Benson). Possibility of tracing lines in the two dimensions of the plane.

-- on an image reconstituter (vizir, visumat,...) each pixel is colored according to the color assigned to its category.

#### V. Chronosequential or Diachronic (Multitime) Processing

The spectral signature of objects can change over time, and the use of several dates can make it possible to improve discrimination and identification of objects and to remove certain ambiguities.

### Synthesis Memorandum

/23

In the following pages is a brief summary of the principal conclusions arising from the reading of the various reports studied during the preparation of the seminar (these reports are the subject of resumes provided in the support document, "Analysis of remote sensing experimentation").

These conclusions are formulated for all four areas of application selected (agriculture, forests, management, water), while certain of the phenomena captured by remote sensing are of interest to several of the four selected areas. Therefore, a certain amount of duplication will necessarily be encountered if one is interested in several of the selected themes.

#### Agriculture

/24

The needs of potential remote sensing users in the field of agriculture fall into four main categories:

- I. Inventory data,
- II. Data for management or crop forecasting,
- III. Phytosanitary surveillance -- Assessment of damage,
- IV. Other studies relating to production.

### I

A. Among the inventory data, the tables presenting general studies are concerned with:

#### A.1. The Definition of Homogeneous Zones

Remote sensing makes it possible to pick out homogeneous zones, but it also captures zones of similar appearance whose homogeneity is due to the consistent appearance of a group of characteristics (occupation of the soil, divisions, moisture, etc.). This is therefore a type of perception which is more synthetic than analytic. These zones of similar appearance should be considered more in relation to the idea of landscape. The most interesting results have

come from the photographic interpretation of Landsat visual images (2\* Arzotu in Tunisia, for example) or from Daedalus images, or photographs taken from a balloon (experiment 6) and even from radar images (experiment 5).

/25

The more precise definition of zones suitable for agriculture, or for a specific crop, can be based on thematic maps (geology, pedology, relief, etc.). Remote sensing can be integrated into the process of drawing up these basic maps (4 for geology, 9 for pedology).

#### A.2. Preliminary Inventory of Soil Use According to the Specification Appropriate to the Needs of the Department of Agriculture

The required specification is never supplied in the work analyzed. It is not adapted for remote sensing, which perceives appearances (e.g., the difference between recent clearing and a natural meadow is not particularly apparent). The seeking of objects on the ground is basically handled by the Landsat classification of numerical data.

The proposed specifications are cruder, in 4 categories: LSA (land suitable for agricultural use), forests, water, abiotic (3 and 36). Sometimes they cannot discriminate a given category but, on the other hand, they give a detailed account of some others (28 and 37). Only experiment 47 (methodology of setting up a data base for soil use in Moselle by means of remote sensing) approaches a category near the required specification.

The main problems involve:

- scattered wasteland and clearings, few in number and small in area. The present resolution of the Landsat satellites (80 m) does not allow a good perception of this category. Moreover, the physical aspects of these formations makes them resemble meadowland and forests.

- vineyards and orchards are often poorly distinguished. Their spectral response is closely linked to the degree of soil coverage by foliage and to the treatment of the zone (grass or tillage).

/26

- the LSA is a heterogeneous category whose great variability makes perception difficult. However, it can be arrived at by distinguishing it from other categories (3).

#### A.3. Five Level Specification

In this case, too, the specifications provided in the experiment do not agree with the required ones. The distinctions hoped for even include species (wheat, barley, peach trees, etc.). This seems impossible for the moment, especially for grains.

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\*The numbers in parentheses refer to "L'analyse bibliographique d'expérimentations en teledetection" (Bibliographical analysis of experiments in remote sensing), OPIT-CNES document, January 1980.

The projects seeking to attain specifications of such precision involve automatic classification of numerical data from Landsat or Daedalus. The problem of resolution arises here, once again, to a degree which increases as the classifications are more precise.

Distinctions may appear according to the stage in the life cycle of the plant (for example growing or harvested wheat: 14, 38, 31, 43 and 45). Similarly, the presence of hedges results in specific spectral behavior, and partially wooded zones stand out well (38).

The classifications arising from unsupervised processing are interpreted a posteriori so that categories within the specification are often composite (meadowland + forest, etc.) (14, 38 and 43).

B. Where specific inventories are concerned, no experiment restricted to a single crop has been undertaken in France. The only experiment of this type is the American LACIE program on world wheat production, but it does not involve our country. For the moment we must therefore be content with the studies which include the desired category /27 in their specification. For the problems encountered (resolution, etc.), it is sufficient to refer to Section A.3. We should add that the choice of a date for collecting data, or a particular channel, is always a compromise between the best possible perceptions of the various crops.

The specific inventories list the main types of crop:

B.1. Grains and Corn

\*Straw

We added a category headed "straw" to those requested. Straw seems to show up well because of its distinctive appearance (38, 40, 45).

\*Wheat

As we have pointed out, the American LACIE program is based solely on the recognition of this grain, and its results, overall, are mediocre.

The "wheat" category is frequently found in specifications. It is sometimes divided into several classes according to the stage in its life cycle (growing wheat, for example: 43). Distinguishing it from other grains is very difficult, and confusion can arise with dense natural vegetation.

\*Other Grains

No inventory study exists on other grains. Several very important preliminary results have been encountered on the spectral behavior of barley (55) and oats (26).

\*Corn

This plant is difficult to recognize. Confusion is frequent,

most often with meadowlands and young forest plantations.

#### B.2. Permanent Woody Crops

These categories are difficult to evaluate. The appearance of vineyards and orchards makes them blend into forests if the plantation is dense, or into active crops and meadowlands if the plantation is sparse. The mode of treatment of the zone (grass or tillage) also influences the spectral responses.

#### B.3. Forage Areas

The prairie category is often found in the classifications. It is well known that there is possible confusion with corn or forest zones. In unsupervised treatments, this category is often divided into several classes according to humidity, presence of fencing, or the manner of use. It may also be a composite category (prairie + foliage, for example).

#### B.4. Other Crops

Not much has been done except in the context of the American CITARS program, a study on soya whose results are not known to us.

#### Conclusions on Inventory Problems

In the area of carrying out general or specialized inventories, the short-term contribution of remote sensing should therefore be restricted to continuing studies of the vegetation cover either from year to year (changes in use) or in relation to a "usual average" on a given date (detection of growth disturbances in order to direct the use of traditional, less synthetic and more costly methods: aerial photos and ground surveys).

In the longer term, it might become possible to carry out directly the important forecasts, on the sole basis of meteorological and remote sensing data, after processing with the aid of sophisticated agricultural/meteorological models now being developed.

## II

From a general point of view, the specific needs relating to management or crop forecasting problems include:

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#### Irrigation

Photographic interpretation of infrared color photos has made it possible to distinguish irrigated zones in a small area of the Beuce. The results are encouraging, although somewhat limited. The rainfall situation at the moment of data collection may greatly disturb the analysis.

## Drainage and Humid Zones

The systematic study of humid zones is only undertaken in "Analysis of a Landsat image of Languedoc (37)" and "Analysis of rural landscapes and moisture content of the soil (45)." Moisture lends a distinctive appearance which is easy to perceive. However, better quantified relationships remain to be established between the spectral responses and the scale of the phenomenon.

## Windbreak Hedges

The presence of hedges is detectable. The resolution of the receivers, too crude to discern a clump of trees, results in the fact that the overall spectral response integrates windbreaks of trees, which are thus distinguished quite clearly. This was found in a number of studies.

Two experiments deal with a more exact spotting of hedges, either by radar (5) or by thermography (27).

Requirements for management and forecasting of crops are also listed by the main types of crops.

/30

### A. Grains

The yield cannot at present be forecast with the aid of remote sensing.

Continuous studies of the stages in the life cycle do not seem to be impossible, but have not been tried.

### B. Permanent Woody Crops

The problems linked to these crops are not studied. Many parameters (conditions of the first stage of formation of the fruit, physiological dropping of fruit) are not accessible to remote sensing.

Only suitable zones can be defined on the basis of thematic maps: pedology and geology, among others (see A.1).

### C. Forage Areas

Here again, little specific work. A few attempts to define a relationship between spectral measurements and the biomass, or activity of the existing vegetation (2 and 40).

### D. Other Crops

No known studies.

### E. Other Studies for Management or Forecasting of Harvests

Here we have added the theme "method of cultivation" in order to group the results relating to methods of cultivation in the various experiments.

The other themes are not dealt with in the projects which were analyzed.

### III

#### Plant Health Surveillance and Evaluation of Damage

/31

Plant health status has not been the subject of any experimentation in the agricultural field.

Among natural disasters, only drought has been analyzed. A qualitative study dealt with photographic interpretation of Landsat visualizations (31b on the Loire Valley). A quantitative study carried out under the LACIE program dealt with a combination of Landsat numerical data (53).

Other accidents have not yet been studied.

### IV

#### Other Studies Linked to Agricultural Production

The snow cover in the Pyrenees was the object of an interesting study which meets the need for a "study of the snow cover."

The problem of abandoned zones, or zones currently being abandoned, by agriculture, found only disappointing results; the perception of waste land and cleared ground is very difficult, as these areas are often small and scattered. The resolution of the satellites is not adapted to the analysis of this phenomenon, and no other type of image seems to have been studied from this point of view.

#### Forests

/32

The needs expressed in the area of forests and natural formations of vegetation refer to four basic themes:

- inventories,
- management,
- accidents and vulnerability to accidents,
- the leisure role.

Needs which could not be classified under one of these four headings were grouped under a fifth, "miscellaneous."

#### Inventory Data

The attribution of priority levels to inventory data requirements proceeds from the most general to the most specific, so that we finish with parameters which are integrated with forest management



problems. The most general consists of isolating the forest from all other types of soil use; the most specific, of recognizing maturity for different species and types of formation.

The forest/non-forest distinction, subject to a precise definition of a forest, seems to be an accomplished fact, on condition, however, of selecting data on appropriate dates. Young plantations, up to about 10 years, are not classified as forests (confusion with waste land, for example).

The Limousin experiment (3) carried out on a single image from April 1976 brings out only mature forests and underbrush with dense forest: simple brush, as well as young plantations, are not classified as forest; on the other hand, there is some confusion, even at the cartographical level, between rivers and forest.

The Loire Valley experiment (31) in July 1975 shows that a degree of confusion can arise between forest, meadowland and corn (especially in the case of young deciduous trees).

The Languedoc experiment (37) underlines the problems of specifications for the Mediterranean zone. The category is obtained by combining 14 basic categories for which the classification criterion is whether leaves remain on the trees all winter. It is not possible to distinguish those species which are considered to be forest trees from those which are not considered as such. The forest-brushland-heathland distinction is perhaps not satisfactory as such in the context of a rigid specification, but cartography shows clearly the boundaries between major ecological zones. /33

Studies on the Montargis forest (23) and the Vosges mountains (22) show the importance of the choice of date for distinguishing the forest category.

In the Vosges the forest category is calculated on the basis of a collection of 13 basic "species" categories. Without prejudicing the quality of the species results, the forest theme is supplied to better than 90% with very good cartographic superposition in relation to other existing documents.

In the study of the Vivarais (22), there are difficulties in defining the forest, but also others arising from the relief and the Sun (September 1976).

The visual analysis of the primary channels or colored compositions can be sufficient, on condition that calculations are based on judiciously selected dates. It seems that the most favorable dates are generally in summer (problem of brush which is not visible in spring, while that period is also quite satisfactory for the forest/non-forest distinction).

Where the results of classification are concerned, they are more satisfactory when the study deals only with the forest theme, even when the question is approached by combining categories, whatever their theme may be.

Certain ambiguities may arise:

/34

- confusion or omissions which may occur in carrying out multi-time data processing or photographic interpretation based on forms and proximity.

- in defining the forest: there is no exact correspondence between the limiting specification for the forest inventory and a specification which may be constructed on the basis of classification results.

Where waste land, cleared land, brush and heath regions are concerned, we are dealing with very varied types of soil use, sometimes defined in terms of function and not in terms of physical parameters. Confusion is frequent from meadowland to forest.

The inventory of partially wooded areas and linear formations is very difficult if not impossible with the Landsat satellite's ground resolution of 80 m: either these configurations "disappear," or they appear exaggerated. The use of radar and studies using thermal infrared seem promising, at least for the definition of partially wooded landscapes.

Cartography of forested areas according to the type of deciduous or coniferous population is quite well carried out, with the same condition as that previously specified for the general inventory, namely, the choice of date. Channels 4 and 5 are more discriminating in winter, channels 6 and 7 in summer. Channel 7 may be sufficient to distinguish deciduous from coniferous, essentially at the beginning of spring and in the case of almost pure stands.

However, certain reservations must apply:

- there is a possibility of confusion between water and coniferous stands. Deciduous trees in the vicinity of water are most often classed as conifers. Confusion is also possible, especially in mid-spring (and, it seems, also in autumn) between deciduous trees, meadowland and corn.

- trees which retain their leaves during the winter in the Mediterranean regions are classed with the conifers.

/35

- the problem of location, relief, and sun exposure has been little studied, but it seems that deciduous trees in the shade are also classed with conifers.

Channels with better adapted wavelength, and the best possible choice of dates will make it possible to resolve many ambiguities.

The classification of forests by species does not, at present, seem to have been accomplished. The species alone is not a sufficient criterion for discrimination, unless it is possible to make use of a time period corresponding to distinct physiological differences between species. Experiments in the Vosges and the Vivarais,

where the classes were based on species, tend, instead, to bring out classes of deciduous or coniferous forests having the same population structure.

Poplars are difficult to distinguish from other wooded formations with Landsat data. There are, however, grounds for optimism, according to the results of studies carried out in the context of "Agreste" in the Po Valley. A higher ground resolution is necessary. The choice of date is also, certainly, of the greatest importance.

The mode of processing and the structure and age of the trees are parameters which certainly influence the spectral response. The Montargis experiment has already shown that it is possible to show the differences between mature forests according to broad age categories and underbrush and different densities of cover. In the forests of Fenetrance and Hagenau, the different classes assigned to species actually correspond more to life stages of the forest.

To sum up, on the subject of problems connected with inventory data, concrete results have already been obtained, and there is growing encouragement. It would be desirable: /36

- to have a better ground resolution for the inventory of all formations which do not take the form of large masses, since Landsat's 80-m resolution is sufficient for fairly general inventory data and has the advantage of not individualizing particular phenomena to an excessive degree.

- to study the possibilities offered by receivers other than those which work in the visible spectrum and the near infrared, and for such receivers, to do more investigation into the definition of the wavelengths to be selected.

- to have sufficient repetitiveness to get a clearer perception of the contribution of each date taken individually or in multitime.

- to review the traditional specifications, and weigh the advantages and disadvantages which they present with respect to the phenomena which we can hope to perceive by means of remote sensing, and also to consider the need for certain data which, apart from the interest of the inventory itself, are possibly not of great importance in other respects.

In the short term, remote sensing could facilitate and reduce the burden of stratified survey plans in the case of forests which are sufficiently homogeneous, on a scale compatible with the size of the pixels. In the longer term, the introduction of new receivers (better resolution, better adapted spectral bands) could make direct identification possible.

### Management Data

The volume and growth of standing timber are linked to other parameters studied in the inventory data, for which we do not

always have an answer. The two experiments presented in the bibliographical synthesis show two different approaches based on radar or on infrared color photos: they apply to only two very specific types of wooded formation (maritime pine forest on waste land, poplar) for which the height of the tree or density of cover can be related to the volume of standing timber.

/37

The real time study of forest harvesting has not been resolved, if only because of the present time lapse involved in obtaining data and the impossibility of having "all-weather" recording.

Continuing study of forest clearing seems a possibility, at least within a large forest (clear cutting without abandoning forest status), on condition that this cut represents an area of 4 to 6 hectares.

The systematic continuing study of forest clearing would require multitime processing and better ground resolution since, while cleared areas can be located quite successfully, errors in estimating their extent are considerable in the case of clearing operations covering a few hectares.

No experiment has taken into account the need for continuing studies of plantations several decades old, on which it would be of interest to conduct continuing studies of behavior and health status.

Continuing studies of artificial and natural wooded areas require a ten-year wait before the young population is classed as a forest. If the ground is not ploughed, these young plantations are confused with clearings.

### Vulnerability and Accidents

/38

No study dealt with the basic need for a knowledge of the vulnerability of forests to fire: the parameters which would make it possible to measure this vulnerability should, without doubt, be specified.

Remote sensing brings a solution to forest fire statistics based on the photo interpretation of raw data or colored compositions or more or less complex processing systems. Only surfaces burnt over within the year are detected. Landsat's channel 7 yields the most information. However, fires in progress are difficult to detect.

The threshold of detectability of the burnt surfaces depends, on the one hand, on the vegetation cover, and on the other hand, on the resolution powers of the receiver. The evaluation of the burnt surface is good in the case of fires of over 10 ha for tall trees, or over 20 ha for short ones. Multitime processing makes it possible:

- to remove certain ambiguities between fires and mineralized surfaces,

- to know what kind of wooded formation has burned.

The reconstitution of wooded zones requires multitime processing and the solution to certain inventory problems (forest/non-forest distinction, continuing study of natural wooded areas). Old fires, while not detectable as such, may still no longer be classed as forest and therefore still be distinguished without being attributed to a particular class.

The susceptibility of forests to disease, parasite attacks or natural phenomena has not been studied.

In the evaluation of zones attacked by disease, parasites and natural phenomena, several interesting experiments have been conducted, but a general study, both spatial and for other species, has not been attempted.

The study dealing with the evaluation of the cochineal infestation in the maritime pine forests of southeastern France (25), even though carried out on the basis of very large-scale photographs, on particular sectors, permits us to conclude that this could be a relatively simple means for detecting, by means of remote sensing from space, large-scale insect attacks, at least in forests of the same species as the one studied. /39

#### The Forest as a Leisure Resource

No elements were found concerning this functional aspect of the forest.

#### Miscellaneous Needs

The definition of forest or ecological zones has not been conducted systematically, but the results of several experiments show clearly, in broad terms, the boundaries of ecological zones (experiments 22 and 37).

Estimation of the biomass would require, first, that the concept of biomass be precisely defined. Two experiments (1 and 24) show possibilities of finding a biomass indicator (?), or perhaps an indicator of foliage mass.

#### Development

/40

A preliminary investigation was carried out among potential remote sensing users. Its aim was to identify their current problems in the context of the completion of the tasks assigned to them, and it offered the possibility of drawing up a series of requirements.

These requirements fall into the following major categories:

- inventory data (dynamic cartography of soil use),

- basic cartography: major zones (topography, geology, climate, ecosystems, etc.),

- management and development of the natural spaces (elaboration of development plans for the major types of environment: urban, agricultural, forest, mountain, coastal),

- human activities (careers, tourism).

It was stated clearly from the start that the formulation of these requirements should not take into account the ability of the resources and methods of remote sensing to fill them.

The introduction of a new tool generally causes the appearance of new requirements which have not necessarily been listed or even perceived.

This report discusses the phase of synthesis between the requirements and the experiments conducted in recent years by research and production organizations. This initial synthesis makes it possible for us to issue an opinion on the limitations of this tool.

It will ultimately be possible to reassess the formulation of needs in terms of remote sensing and, if necessary, to propose new orientations for studies of the environment which could simultaneously satisfy both the manager and the physical description of phenomena. /41

## I. Inventory Data

Inventory tests on a national level have used data from the NOAA satellite.

The cartographic documents obtained are on a scale of 1/2,500,000. Processing on two dates (separately and jointly) makes it possible to classify the entire territory under major specification categories and to demonstrate the dynamics of the major types of environment.

There are significant confusions in the categories of the specification, and the "classes" obtained are far from the requirements for the four-category description of the territory (urban, forest and natural environment, open water, land suitable for agriculture).

The solution would lie in a juxtaposition and synthesis of regional experiments using Landsat data. Problems remain to be solved in relation to such a "mosaic" of results (discrepancies in image-taking times, difficulties of covering the entire territory in a given period, without clouds, etc.).

The cartography of Haute-Vienne (3), the analysis of the Languedoc image (37), the photo interpretation studies of Landsat images in the Loire valley (45), the soil-use cartography in Moselle (47) are all experiments which enable us to hope that results may be obtained through this approach.

In general:

/42

- open water surfaces are clearly detected.

- the "forest/non-forest" distinction is possible in the case of old, clearly defined forests. Problems of confusion with agricultural land arise chiefly in the case of brush and the Mediterranean forests.

- the two other categories (urban and land suitable for agriculture) are more difficult to discriminate.

Landsat's resolution (80 m) seems well adapted for an overall image of France through its smoothing out effect, which is beneficial when dealing with small scale units.

Attempts at regional cartography, with detailed specifications, have had varying results: specifications in terms of plant species are difficult to map by remote sensing, which classes the species by "appearance" (color, biomass, structure).

Specifications in terms of function are in any case to be rejected, since they are based on our mental perception of objects and not on their physical reality.

Improved resolution would allow us to study small divisions on a larger scale and to avoid, in part, the confusion between elements due to the border effect (at 1/25,000).

Experiments dealing more specifically with the agricultural and forest areas are set out in detail in their respective syntheses.

The urban environment is the subject of various studies:

/43

An experiment on the Parisian agglomeration (32): three principal conclusions arose:

- the classic specifications, which too often involved the aspect of function, are not adapted.

- the Landsat resolution is poorly adapted to the fine degree of cartography desired.

- it is necessary to bring in topological parameters to specify forms and their positions.

This concept of topology would, moreover, be very useful for all cartographical approaches to the territory (these studies, which require extensive and complex data processing systems, are now being developed).

A study on Arles with the finer resolution of the airborne Daedalus receiver (17 m) allowed an additional separation into two types of individual dwelling, according to the proportion of active vegetation around the dwelling, and definition of linear boundaries and

infrastructures which are less vague in appearance than with Landsat.

Mountain zones were the subject of what was essentially a forest inventory, but the land-use cartography is severely disturbed by differences in lighting resulting from the relief.

Numerous studies deal with coastal sites (5, 15, 16, 18, 34, 38). Apart from the cartography of land areas near the coasts, where the common problems relating to the inventory of soil occupation were encountered, these studies permit an approach to the aquatic environments (foreshore, tidal flats, etc.) which would, moreover, be difficult by other methods.

Exchanges between the sea and ponds, currents, depth measurements, etc., can all be charted by airborne thermography.

/44

## II. Basic Maps

While the soil-use inventory maps were obtained primarily by the numerical processing of Landsat bands, basic cartography (geology, pedology, rural landscapes, etc.) remains essentially in the domain of photographic interpretation.

Aerial photos, photos taken from stratospheric balloons, primary channels and Landsat colored compositions are interpreted visually to determine zoning.

In topography, the composition and updating of topographical maps by remote sensing is currently underway at IGN.

In geology, photographic interpretation most notably permits a description of fracturing and structural geology. Lithological boundaries can be traced, if necessary, but soil identification can be carried out only by surveys on the ground using remote sensing documents as a support for geological research.

The approaches are very diversified and complementary: aerial photos, thermography, radar images, airborne scanners and space scanners.

The availability of stereographic SPOT data will be of considerable help.

In pedology, ground studies and the analysis of aerial photographs (colored equidensity, chromatic selection and combination, maculometry) make it possible to chart soils (8, 9).

Rural landscapes were obtained by photographic interpretation of a Landsat image of the Loire valley (45).

In addition, soil-use studies, with detailed specifications (e.g., processing of the Languedoc image, No. 37), can have repercussions in terms of broad zoning; it is possible to trace, based on the results of the classification, the boundaries between the major ecological sectors of Languedoc-Roussillon.

/45



A "dynamic" zoning study was carried out in Tunisia as part of the ARZOTU program (2) and will be applicable in France: by photographic interpretation of Landsat colored compositions at different dates during the year, a dynamic map is obtained of units of similar appearance (frequency of observation of units, permanence of boundaries, etc.).

### III. Management and Development of Natural Spaces

Inventory data and basic cartography are a point of departure for the management and development of natural spaces.

Establishing a natural park, the route of a highway, or a continuing study of the encroachment on natural space by urbanization are tasks in which remote sensing can play a role to a greater or lesser extent.

The example of the mapping of the snow cover (46) is typical in its potential applications:

#### continuing study of snow cover over a winter

- assessment of downstream flow by studying variations in the surface of the snow cover;
- forecasting avalanches;
- reforestation;
- availability of high-altitude pastures;
- programming of snow removal;

#### continuing study of snow cover over several years

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- influence on soil formation;
- introduction of tourism;
- knowledge of large-scale climatic phenomena.

### IV. Human Activities

Remote sensing can involve many other human activities apart from agriculture and urban development. In demography, for example, there are experiments on the attendance at tourist sites and on the rate of occupancy of secondary residences.

These have not been analyzed at the time of writing this report. They use data from airborne sources: counting the attendance at the Camargue beach in Bouches-du-Rhone on aerial photos taken at an oblique angle, and estimation of the percentage of residences using heat on winter thermographic recordings.

The search for a continuing equilibrium in time and space, in quantity and quality, between supply and demand, requires an accounting system for availability and use:

- precipitation (rain and hail, snowfall),
- distribution and circulation of continental water:
  - snow and ice cover,
  - retained water and humid zones,
  - underground water,
  - flow of waterways, forecasting and surveillance of floods,
  - irrigation and drainage;
- sediment and pollution in open water (interior and coastal) and their distribution:
  - salt water/fresh water boundary,
  - natural or artificial sediments,
  - water pollution, thermal waste;
- "water" ecosystem:
  - hydrobiology.

For the purposes of forecasting and model development, it is also necessary to detect the factors which determine the future of precipitation and the distribution of continental water:

- run-off,
- water content of the soil,
- evapotranspiration,
- dynamics of water masses,
- depth measurements.

The means for measurement of the resource should be implemented in the best possible manner:

- implementation and management of "ground" networks for hydrological measurements.

In addition, it is desirable to determine and follow the mutual influences of man and his activities (developments, use,

pollution, etc.) with the water environment:

- development of waterways, impact studies,
- management of interior waterways,
- management of coastal waters.

#### A. Precipitation (Rain and Hail)

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Rain and hail are shown:

- by their direct effects: weakening or reflection of radiation (especially radar waves) by atmospheric water (i.e. by the precipitation itself),
- by secondary effects: water in the soil and in the plant cover.

The observation of the direct effects has already been carried out by radar installations based on the ground; it does not appear that such results have been obtained in France using radar aboard aircraft, and a fortiori from a satellite; interesting aerial observations of rains associated with cyclones are said to have been carried out in the United States.

The observation of the secondary effects depends on methods comparable to those relating to the evaluation of irrigated areas. This application calls for very frequent observations.

#### B. Snow and Ice Cover

The snow cover is characterized by two main parameters:

- its extent,
- its thickness.

The extent of the snow cover (detection of the snow/no-snow boundary) can be observed in the visible spectrum:

- the steeper the relief in the observed zones, the higher the necessary ground resolution,
- certain problems of snow/cloud confusion could be resolved by observations in the intermediate infrared spectrum.

Depth (and state) of the snow cover:

- cannot be directly detected in the visible spectrum,
- can be evaluated in the intermediate infrared.

#### C. Retained Water and Humid Zones

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Inventory of humid zones:

- humid zones of an area of less than 3 pixels (the basic "point" in ground analysis) are not detected,

- a pixel identified as water is almost always water (in 90 to 95% of cases, for observations in the visible spectrum and very near infrared),

- therefore, in general, in small-grid zones (Haute-Vienne, etc.), the total water area of the department:

- is underestimated (factor 2) by observation of Landsat images,

- will probably be detected with significant precision on SPOT images.

Following the short term evolution of certain humid zones is possible only to the extent that this evolution is significant in relation to the size of the pixel.

Coastal ponds:

- the analysis of thermal fronts (in the infrared) makes it possible to show:

- stable water masses (straight-line front),

- moving water masses (undulating front) and the direction of flow between the sea and ponds,

- turbidity (suspended matter) can also constitute an indicator, observable in the visible spectrum, of the dynamics of water masses in ponds,

- zoning, in the visible spectrum, of the waters of these ponds does not outline zones of equal water qualities, but complex combinations of "nature of bottom/depth/presence of marine vegetation/turbidity, etc."

#### D. Underground Water

Boundaries and structures of water-bearing zones:

- observations in the intermediate infrared allow:

- the detection of loss zones and the emergence of underground water levels,

- the demonstration of ground fracture lines (which are important for the circulation of fluids),

- observations in the thermal infrared make it possible to draw up thermal maps which facilitate the location of circulating of fluids near the surface of the ground,

- radar observations facilitate the demonstration of fractures: the corresponding methodologies are being perfected. /50

#### E. Rate of Flow in Waterways - Forecasting and Surveillance of Floods

Observation of rate of flow:

- no direct method of observation seems to be under study in France,

- rate of flow can be calculated using hydropluviometric models which use, in particular, "soil occupation" information.

Observation and continuing study of flooded zones:

- this application can benefit from methodologies which have been developed:

- for the inventory and continuing study of humid zones (Section C),

- for the evaluation of the water content of the soil (Section L).

The evaluation of the impact of human activities on the behavior of waterways: this application requires observation and continuing study of rates of flow and flooding before and after "developments" have been carried out.

#### F. Irrigation - Drainage

Determining zones to be drained:

- this application can be studied using various indicators:

- water content of the soil (Section L),

- state of vegetation and crops (agricultural theme).

Surveillance of the effectiveness of existing installations: this problem is of the same nature as the preceding one (an equipped zone which appears like a zone suitable for drainage does not have effective installations).

Inventory of irrigated zones:

- in semi-arid regions (California, for example), such an inventory is easily carried out: in summer only the irrigated zones are green,

- in temperate regions such as France, the problem is more difficult:

- for a given zone, photographic interpretation of Landsat's channel 7:

\* permits identification of irrigated surface with an accuracy of 90%, in dry weather,

\* can lead to deviant results in case of recent rain,

- the transfer of methodologies from one region to another calls for in-depth knowledge of the zones under study (soils, climate, elements of the landscape),

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Estimation of performance of the methods of irrigation used: significant information can be deduced from compared observations:

- of the appearance of the zone under study,

- of the appearance of the zones of reference, irrigated or not irrigated, respectively.

Determination of the potential for irrigation (proximity to water reserves and/or traditional methods of irrigation): observation of soil occupation of the region concerned yields some elements of a solution to this problem.

#### G. Salt Water/Fresh Water Boundary

The currently available means of observation (visible spectrum, infrared, thermal) do not allow us to discern the different levels of salinity.

Salt water/fresh water boundaries cannot be outlined unless they are simultaneously the site of other phenomena (Section C, Coastal ponds):

- visual (color and/or turbidity of water),

- thermal.

These thermal phenomena make it possible, for example, to detect underwater surges of fresh water which translate into temperature anomalies. These anomalies are more apparent when the contrast, positive or negative, is greater; observation dates should be chosen accordingly.

#### H. Natural or Artificial Sediments

Sediments in suspension may be detected and followed when they translate into phenomena of color and turbidity.

#### I. Water Pollution - Thermal Wastes and Their Diffusion

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Qualitative classification of wastes:

- observation of the color and turbidity of the water, in the visible and infrared:

- permits delimitation of classes of values whose physical meaning is sometimes complex (turbidity, aquatic vegetation, depth, nature of bottom, etc.),

- allows discrimination and study of the contacts between masses of water of different origins,

- the dynamic study of wastes calls for frequent observations (daily and sometimes hourly),

- the choice of appropriate times for observations allows selective detection of natural and artificial wastes,

- in the dry season, and especially at rush hours in tourist areas, the wastes are primarily of artificial origin,

- after a period of rain, natural wastes are added.

#### Thermal wastes:

- observation of the water's surface, in the infrared and thermal spectra, makes it possible:

- to draw up precise temperature charts,

- to detect and describe anomalies, whether positive or negative, in temperature; these anomalies appear more distinctly when the contrast is more marked,

- the choice of appropriate times for taking observations allows selective detection of natural and artificial wastes.

#### Layers of hydrocarbons:

- if they are more than a few micrometers thick:

- can be detected, in a qualitative manner, by all kinds of means (visible, intermediate and thermal infrared spectra, radar, etc..),

- their thickness can be evaluated in approximate terms (thermal infrared, radar under certain conditions),

- to avoid wrong interpretations, it is wise to combine several means of observation,

- the optimal observation methods differ:

- from day to night,

- from clear weather to bad weather,

- from a calm to a rough sea.

#### Accidental pollution:

- frequency of observation and speed of intervention are important

factors in success.

Inventory of sources of pollutants:

- when they take the form of turbid or thermal patches of observable dimensions, these sources can be listed.

Impact of developments on the level of pollution in waterways:

- important information can be obtained by comparing observations carried out before and after the completion of the developments.

J. Hydrobiology

Observation of the color and turbidity of the water in the visible and infrared spectra makes it possible to identify classes of values whose physical significance is sometimes complex (turbidity, aquatic vegetation, depth, nature of the bottom, etc.).

K. Run-off

No direct method of observation seems to have been studied in France.

The collection of information relative to soil occupation (particularly whether rendered impervious to water or not) contributes significant elements.

L. Water Content of Soil

In the visible spectrum, the water content is indicated indirectly by the state of the vegetation and by changes in the physical appearance of bare ground.

Radar observations (at certain special frequencies) make it possible to analyze the level of moisture directly, at the surface and a little below it; it is impossible to carry out this type of observation on rainy days.

M. Evapotranspiration

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No direct method of observation seems to have been studied in France.

Evapotranspiration can be calculated using models based on tables of energy exchange based on parameters of meteorology, soil hydrometry, phenological characteristics of crops, etc.

N. Dynamics of Water Masses

No method of direct observation seems to have been studied in France.

Studies of water currents can be carried out by observing indicators such as:

- patches of pollution (Section I),



- thermal fronts (Sections C and I).

#### O. Depth Measurements

Observations in the visible and infrared spectra yield information on underwater structures:

- however, in general, the information collected does not only describe the bottom; it relates to complex combinations of "nature of bottom/depth/presence of marine vegetation/turbidity/ . . .",
- the limit for detecting the bottom seems to be in the vicinity of 10 meters (French coastal ponds); it is probably much lower in very clear tropical waters.

#### P. Implementation and Management of "Ground" Networks for Hydrological Measurements

In France, no procedures for optimizing the implementation of these networks seems to have been carried out using remote sensing data.

However, it is likely that such procedures would be made easier, where water quality measurements are concerned, by:

- identification of classes of values reflecting water quality (Section I),
- drawing up and regular updating of an inventory of pollution sources (Section I).

#### Q. Development of Waterways and Humid Zones - Impact Studies

Impact studies can be facilitated by comparing observations of the zone concerned, taken before and after the developments have been undertaken, especially regarding: /55

- soil occupation (development theme),
- pollution status (Section I),
- etc.

#### R. Management of Interior Waters - Miscellaneous Needs

Meeting these various management needs can be facilitated by the collection of relevant data, in particular that related to:

- soil occupation (development theme),
- inventory of water retention and humid zones (Section C),
- pollution status (see Section I).

#### S. Management of Coastal Waters - Miscellaneous Needs

Meeting these various management needs can be facilitated by the collection of relevant data, in particular that relating to:

- soil occupation (development theme),
- pollution status (Section I),
- etc.